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(54) Cooling structure for a wall of a propulsion plant

(57) A cooling device made of metallic materials incorporates cooling ducts in the form of cooling pipes or cooling channels for cooling a wall (for example a hydrogen cooled rocket nozzle, hypersonic propulsion plants, and aircraft engines). The device comprises a multilayer plate structure including a carrier plate 1, a cover plate 11, and a composite fiber core structure sandwiched between the two plates. The composite fiber core structure is constructed, of fibers, e.g. carbon fibers or silicon carbide fibers embedded in a heat conducting metal matrix and the cooling ducts 4, such as pipes or channels, are embedded or formed in the fiber composite core structure. The composite fiber core is enclosed on all sides by metal and the entire structure is densified in a hot isostatic pressing step.

FIG. 4

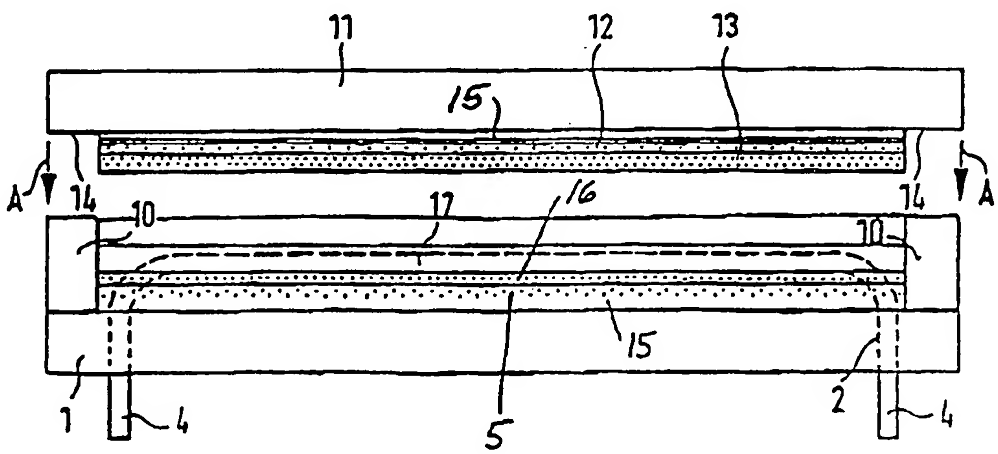

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FIG. 1

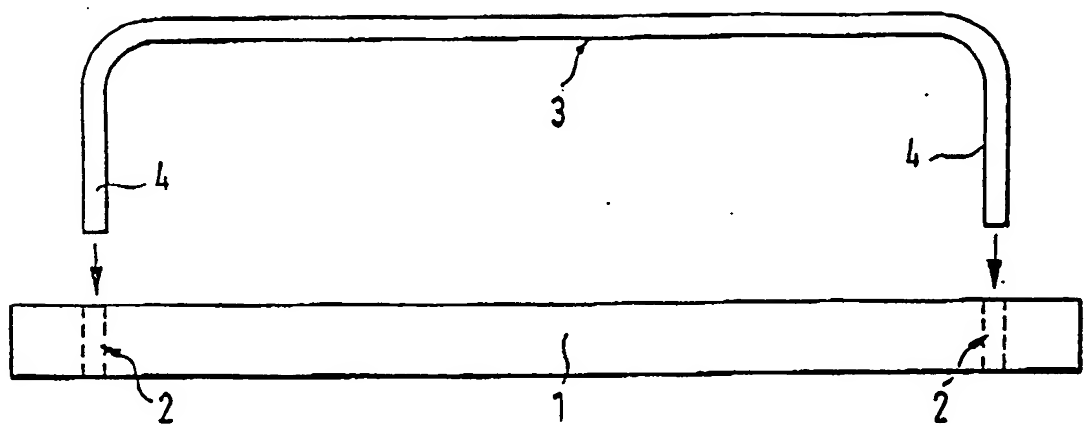


FIG. 2

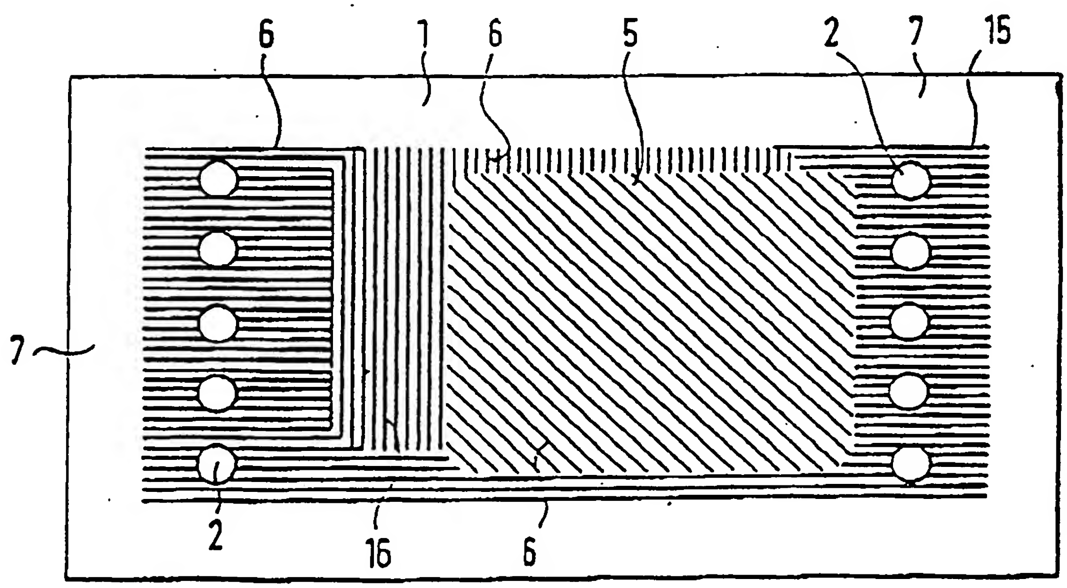


FIG. 3

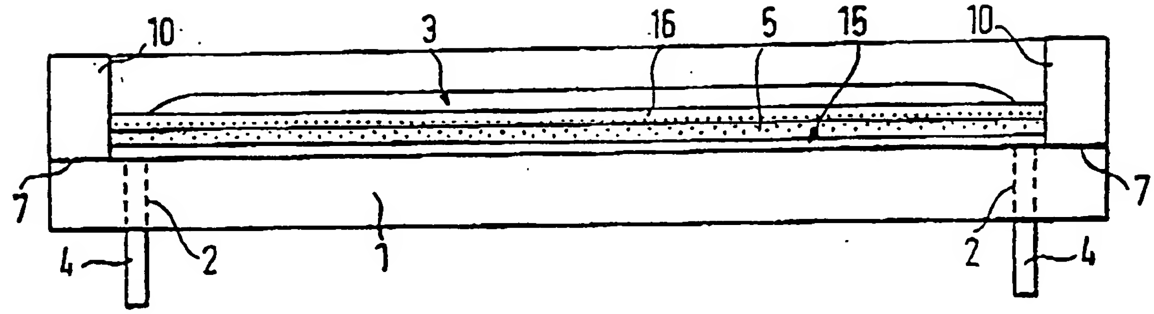
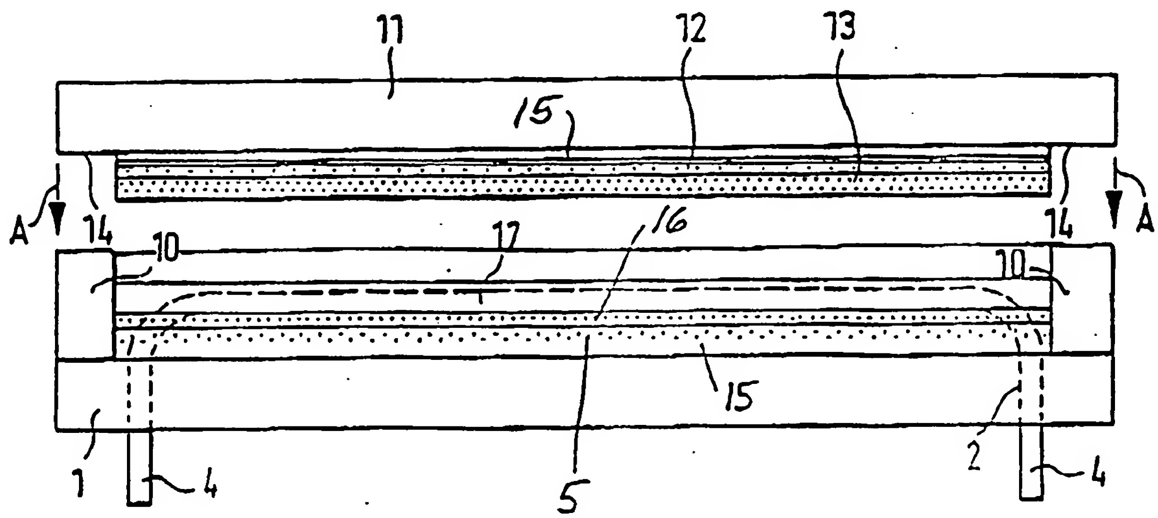


FIG. 4



COOLING STRUCTURE ESPECIALLY FOR A WALL OF A PROPULSION PLANT AND METHOD FOR MAKING SUCH A COOLING STRUCTURE

The invention relates to a cooling device made of a metallic material with cooling ducts provided in the metallic material. The invention also relates to a method of producing such cooling devices which are especially suitable for cooling walls of propulsion plants, for example hypersonic propulsion plants.

BACKGROUND INFORMATION

Conventional cooling structures or devices for cooling walls of a heat source such as a propulsion plant, comprise cooling channels positioned on the wall side facing away from the heat source. A coolant or cooling medium is caused to flow through these cooling channels. The cooling channels are either machined into the wall surface or the channels take the form of cooling pipes which are secured in a heat exchange manner to the surface of the wall, for example by welding, brazing or soldering. The material of the wall that is heated in operation depends substan-tially on the type of the heat source. For example, in chemical equipment exposed to reaction heat sources the walls are made of glass or ceramics. These materials have the advantage that they are resistant to high temperatures and do not require a substantial power for cooling purposes. However, glass and ceramic materials have the disadvantage

that they are brittle so that they break under mechanical bending loads causing bending stress. Additionally, these materials are quite sensitive to temperature shocks and their heat conducting ability or heat conductivity is rather small.

Cooling structures made of metal are described in German Patent Publication DE-PA 4,137,636.2-44. These known cooling devices have the disadvantage of a very complex construction and that they must be made of high temperature resistant, high alloy metals when these cooling structures are intended for use at temperatures and mechanical loads as they occur at the walls of a hot gas turbine, a rocket nozzle, or on the walls of a hypersonic propulsion plant. The high temperature resistant, high alloys comprise, for example, cobalt base alloys or nickel base alloys which are required to take up the thermal loads as well as the mechanical loads. These materials however have several disadvantages. First, they have a low heat conductivity. Second, they are hard to machine or to work. Last, but not least, they are very expensive.

Precious metals, such as silver or gold are not suitable for the above purposes, besides, they are too expensive. Copper and aluminum and alloys thereof have a high heat conductivity, however, they have the disadvantage that at higher temperatures their mechanical strength is limited.

OBJECTS OF THE INVENTION

In view of the above it is the aim of the invention to achieve the following objects singly or in combination:

to provide a cooling structure or device and a method for its production, which device has a high heat conductivity in combination with an improved mechanical strength, whereby its production shall be cost efficient;

to use fiber reinforced composite materials for a cooling structure, whereby cost effective metals are used as matrix materials and/or as cover materials;

to minimize deformation of the cooling structure due to temperature variations;

to facilitate the mounting of the cooling structure to the heat generating source;

to employ metal and fiber combinations which facilitate the working of the components of the cooling structure so that inexpensive mass production methods may be used to make the present cooling devices;

to eliminate or at least minimize solid material reaction effects between the fiber material and the matrix material at operating temperatures;

to minimize expensive machining operations and to use instead simple and hence inexpensive manufacturing techniques;

to protect the components of the cooling structure or device against oxidation, erosion, and corrosion;

to construct the cooling structure in such a way that in series or parallel connections to a wall to be cooled can be made in a cost efficient manner;

to construct a cooling system in such a way that it may simultaneously function as a heat exchanger for preheating purposes; and

to construct the cooling device in such a way that automated manufacturing procedures can be employed for a mass production of these device.

SUMMARY OF THE INVENTION

The cooling device according to the invention is constructed as a multi-layer plate structure including cover plates and

a core layer formed as a reinforced fiber composite structure with fibers embedded in a heat conducting metal matrix in which cooling ducts or channels are provided, e.g. embedded. The core layer may have several plies sandwiched between the cover plates, one of which forms a carrier plate. The present construction has the advantage that a fiber reinforced composite structure forms the load supporting and cooling core layer. Such a structure has the further advantage that on the one hand relatively inexpensive metals can be used as matrix metals and/or as cover plate materials which additionally have a high heat conductivity. Yet another important advantage is the very high mechanical strength of these fiber compound structures.

According to the invention the heat conducting matrix metals and cover plate metals may be selected from nonferrous metals, such as bronze, brass, copper, aluminum, and alloys of copper and aluminum. Thus, a further important advantage of the present structure is the fact that cost efficient materials can be used.

In a preferred embodiment of the invention the fiber reinforced composite structure comprises several fiber layers or plies, whereby the fibers are oriented in accordance with tension loads that occur during operation to take up the respective tension stress. Specifically, the fibers are predominantly oriented in the direction of the tension loads. Thus, a

vaulting and/or warping of the cooling structure is advantageously prevented. The cooling channels within the fiber reinforced composite structure somewhat weaken the core layer. To compensate for this fact, the core layer is provided with uninterrupted fiber reinforced composite plies next to the cover plates. These uninterrupted fiber reinforced composite plies of fiber layers are free of cooling channels. As a result, the structure is capable of safely taking up the mechanical loads to which the present devices may be exposed.

In another preferred embodiment of the invention, a metallic frame surrounds the core layer on all sides to facilitate the mounting of the cooling structure or device. The metallic frame provides a wall element that can be welded, brazed, or soldered all along the edges of the frame. Thus, the metallic frame provides the advantage that in all directions the same working and/or mounting conditions prevail. The frame which closes off the core layer along the sides or margin zones of the cooling structure may be an integral component of one of the cover plates, whereby the frame may be formed as a lateral angular section of one of the cover plates. However, the frame may also be a separate prefabricated element that is secured to one of the cover plates, either the carrier plate or the outer cover plate.

Preferably, the fiber reinforced composite structure is formed of composite fibers comprising a fiber core and metallic

coatings on the fiber cores, whereby these fiber coatings are preferably made of metals that are compatible with the metallic materials of which the cover plates are made. This feature has the advantage that simple working techniques may be employed to form the core layer of a plurality of plies made of composite fiber materials, whereby the plies can be connected to each other by soldering the metallic coatings on the fibers to each other. Welding or sintering or compacting or compression connections may also be employed for interconnecting the plies in forming the core layer so that preferably the fiber structure forms a compact core layer of dense, heat conducting, metallic matrix material with fibers embedded in the metal matrix and cooling channels embedded or formed or provided in the composite material. The metal matrix material may be exclusively provided by the metal coatings on the fibers. However, metal may also be added to form the matrix of the added metal component and of the fiber metal coatings. In another embodiment uncoated fibers are used and the matrix metal is added completely. The preferred fibers or fiber cores are made of carbon or silicon carbide. These fiber materials have proven themselves to be advantageous for embedding nonferrous matrix metals since these materials have a good heat conductivity and a good bonding characteristic for forming strong bonds between the nonferrous metal and the carbon or silicon carbide fibers. The combination of these matrix and fiber materials has yet another advantage in that

no solid material reaction effects between the fiber material and the matrix material occur at the operating temperatures here involved.

In another preferred embodiment of the invention the cooling channels or ducts are formed by cooling pipes. This embodiment has the advantage that no special groove structure needs to be worked or machined into the surface of the carrier plate for the cooling channels. Rather, the carrier plate merely is provided with bores or holes for mounting the cooling pipe ends. The cooling pipes can then be arranged in parallel to each other and tightly close to each other on the carrier plate. The connecting ends of the cooling pipes for the inlet and outlet of the coolant are bent or angled and inserted into the holes in the carrier plate so that the pipe ends extend at an angle out of the carrier plate. The cooling pipes are, so to speak, embedded

in the composite fiber structure because the composite fiber structure takes up space between, above, and below the cooling pipes whereby the pipes and the fiber structure form together the core layer. The core layer is preferably provided with a metallic frame for forming a wall element of a housing through which a hot gas flow passes. The metal frame is secured together with the core layer to the carrier plate, whereby the frame encloses the core layer all around its rim so that the fibers or fiber cores of the fiber composite structure of the core layer do not come into direct contact with the hot gas flow along the rim of the structure and so that the fibers or fiber corers are protected against oxidation, erosion and corrosion.

The bores or holes for the mounting of the cooling pipes may be arranged in one or the other of the cover plates. This feature has the advantage that connector pieces for the inlet and outlet of the coolant to and from the cooling channels or ducts formed by the cooling pipes can be conveniently mounted in the respective cover plate, whereby the connector pieces are preferably angled or elbow pieces extending with one end out of one of the cover plates and having the pipes connected to the other elbow end. This construction has the advantage that a plurality of cooling wall elements can be assembled along their rims to form a cooling wall, whereby the connector pieces for the inlet and outlet of the coolant are not directly exposed to the hot

gas flow. This structure has still another advantage in that a serial or parallel connection of several connector pieces in a cooling wall can be accomplished in a cost efficient manner, because all connector pieces are easily accessible on the side of the structure that faces away from the hot gas flow.

The connection of the inlet pieces forming inlet ports to each other and of the outlet pieces forming outlet ports to each other is accomplished preferably through a manifold pipe or channel made of materials which on the one hand have a reduced corrosion and reduced solid reaction with the surrounding components or with the material of the cooling structure and which furthermore have a reduced solid reaction with the material of the support structure. Manifold pipes of stainless steel for example, have been found to be quite satisfactory. The stainless steel had a chromium content of more than 13% by weight for coolant connectors made of a copper alloy. The stainless steel pipes are connected, for example, with the support structure made, for instance of a titanium alloy, in such a way that the cooling structure or device is maintained in the proper position. The cooling device is made of a copper alloy with a carbon fiber reinforced core layer.

Wall elements for controlling and directing a hot gas flow or stream in propulsion plants or elements for varying the

nozzle cross-section in accordance with operational requirements are cooled by using hydrogen as a coolant. In wall elements used for hypersonic propulsion plants, for rocket engines, or for other hydrogen operated propulsion plants, the hydrogen used as a coolant is simultaneously preheated for its subsequent combustion so that the cooling structure performs two functions, namely its primary cooling function and a heat exchanger function.

The method according to the invention for producing the present cooling structures comprises the following steps. First, holes are made in a cover plate preferably the carrier plate of heat conductive material, whereby these holes will hold connector pieces, nipples or bent pipe ends for cooling ducts formed for example by cooling pipes. Second, a first fiber layer is applied to the carrier plate leaving joiner surfaces along the margin zone of the carrier plate and around the holes formed in the first step free of the fiber layer. Third, cooling ducts are formed by inserting pipes with angled pipe ends or a cooling channel structure is inserted with its inlets and outlets into the holes and through the recesses formed where the first fiber layer is not applied. Fourth, intermediate spaces between the cooling pipes or cooling channels are filled with further fiber plies to form a core layer. Fifth, the carrier plate is joined to a cover plate, thereby enclosing the core layer to form the cooling structure or device.

The just summarized method according to the invention has the advantage that it employs only cost effective manufacturing steps and provides possibilities to produce the present cooling structure in a simple manner, yet achieving a cooling structure made of relatively soft nonferrous metals which structure nevertheless has a high temperature resistance due to the fiber composite construction. Additionally, these method steps are amenable to an automated operation that is quite feasible for mass production.

Prior to joining the cover plate to the carrier plate, the cover plate, on its side facing the core layer, may be provided with a fiber layer, whereby again the joining or joiner faces along a margin zone are not covered by the fiber layer. This feature has the advantage that the core structure or layer can also be provided with a closed fiber structure relative to the cover plate so that the cooling channels or cooling pipes are completely embedded or enclosed by the fiber structure. This closed or uninterrupted fiber layer may also be placed onto the cooling channels or cooling pipes as the last layer of the fiber structure prior to joining the cover plate to the carrier plate.

If the fiber structure is to be produced by using uncoated fibers or fiber cores or if these are only minimally coated

so that the layering of the plies for forming the cooling structure will not result in a closed metal matrix without voids between the fiber cores or fibers, it is preferable that prior to the layering the hollow spaces in the fiber structure are filled with material that is compatible with the carrier plate and with the cover plate. Such materials may be introduced by floating the material into the recesses and voids, by infiltration, by dusting or by any other suitable deposition. Thus, the advantage is achieved that powder metallurgical processes may be used for the just mentioned introduction of the matrix material into the voids between the fibers and fiber cores in order to produce a solid metal matrix without voids when forming the core structure or layer. In a preferred embodiment of the present method, the cover plate and the carrier plate are joined to each other while enclosing or sandwiching the core layer between the two plates. The joining is accomplished by welding or soldering or brazing to form a noncompacted wall element. The compacting is performed after the joining. The compacting is performed, for example, by a hot isostatic pressing of the wall element or cooling device that was initially not compacted.

Another preferred performance of the present method connects the connector pieces or nipples or the bent pipe ends in a gas-tight manner with the holes in the carrier plate as a result of the joining. Thus, the advantage is achieved that

no gas exchange can take place through the lead-throughs formed by the connector pieces, nipples, or bent pipe ends in the carrier plate between the core layer and the atmosphere. However, it is nevertheless preferred to evacuate the core layer during the joining. This may be done by performing the joining in a reduced pressure enclave. Thus, it is possible to isostatically press the cooling structure immediately following the joining, whereby the core layer and the matrix material in the core layer are densified.

If the core layer is to be evacuated after the joining, as is preferred, evacuating nipples are to be provided between the carrier plate and the cover plate. These evacuation nipples are closed again in a vacuum tight manner after the evacuation is completed. During the following hot isostatic pressing of the cooling structure with its enclosed evacuated core layer, the core layer is densified to a compact layer of a metallic matrix material having embedded therein the fiber cores and cooling channels or ducts, whereby simultaneously the connection of the carrier plate and the cover plate with the matrix material is accomplished.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be clearly understood, it will now be described, by way of example, with reference to the accompanying drawings, wherein:

Fig. 1 shows a side view of a carrier plate with holes and a cooling pipe prior to insertion into these holes for forming the present cooling device;

Fig. 2 shows a top plan view of the carrier plate having applied thereto a closed first fiber layer and holes for the cooling pipes not covered by the first fiber layer;

Fig. 3 shows a side view of the present cooling device still without the cover plate but carrying the cooling pipes and several plies of a fiber composite material enclosed by an all-around frame; and

Fig. 4 shows a side view prior to the assembly of the cover plate, the bottom plate, and frame, whereby the cover plate also carries several plies of the fiber composite structure.

DETAILED DESCRIPTION OF PREFERRED EXAMPLE EMBODIMENTS AND OF THE BEST MODE OF THE INVENTION

Fig. 1 shows a carrier plate 1 for a cooling device according to the invention. The carrier plate 1 is provided with bores 2 for mounting cooling pipes 3 with their bent ends 4 into these holes 2. The pipe or tube ends 4 are bent over to form an elbow shape shown in Fig. 1. The pipes or tubes 3 are made of a copper alloy and these tubes form the cooling ducts or channels. The bend of the tube ends 4 is preferably a 90° bend. The carrier plate 1 is also made of a heat conducting metal such as a copper alloy into which the holes 2 are bored for the insertion of the tube ends 4.

As shown in Fig. 2 prior to the drilling of the holes 2 the carrier plate 1 is provided with a substantially uninterrupted first fiber composite ply 15 which does not cover an all around margin zone 7 of the carrier plate 1 and which also does not cover the area where the holes 2 are to be drilled. The fibers 6 of the first ply 15 shown in Fig. 2 are oriented in accordance with the tension loads that are effective during operation of the present cooling device. In the shown example the fibers are carbon fibers which have been galvanically coated with a copper alloy.

In a preferred embodiment the carrier plate 1 is made of substantially pure copper, except for naturally occurring

impurities and the cooling pipes 3 are made of a copper nickel alloy including 10% of nickel by weight, the remainder being copper and naturally occurring impurities.

Other materials tested and found suitable for the present purposes for making the cooling pipes or tubes 3, the carrier plate 1, and the cover plate 11 as well as the matrix material, are selected from chrome alloyed coppers comprising 0.5 to 5% by weight of chromium, or aluminum bronze containing 4 to 10% by weight of aluminum the remainder being copper and additive elements such as Ni, Fe, Sn, Si and Mn . Aluminum alloys may also be used for the present purposes. These aluminum alloys have, compared to copper alloys, the advantage of a smaller specific weight. For example, the cooling pipe 3, the carrier plate 1, the cover plate 11, and the matrix material may all be made of the following aluminum alloy containing

3.8 to 4.9% by weight of copper,
1.2 to 1.8% by weight of magnesium,
0.3 to 0.9% by weight of manganese,
and the remainder being aluminum and naturally occurring impurities.

Another suitable aluminum alloy has the following composition.

2.2 to 2.7% by weight of lithium,
0.5 to 1.2% by weight of magnesium,

1.0 to 1.6% by weight of copper,
and the remainder being aluminum and naturally occurring spurious elements or impurities.

Still another aluminum alloy suitable for the present purposes comprises

5.1 to 6.1% by weight of zinc,
2.1% to 2.9% by weight of magnesium,
1.2 to 2.0% by weight of copper,
and the remainder being aluminum and naturally occurring spurious elements or impurities.

Yet another aluminum alloy for the present purposes comprises

0.8 to 1.2% by weight of magnesium,
0.4 to 0.8% by weight of silicon,
0.15 to 0.4% by weight of copper,
and the remainder being aluminum and spurious naturally occurring elements or impurities.

Brass has also been found suitable for the present purposes to make the cooling pipe 3, the carrier plate 1, the cover plate 11, and the matrix material. A suitable brass contains 30% by weight of zinc, the remainder being copper.

Another copper alloy containing 10 to 20% of tin and 1 to 5% by weight of titanium, the remainder being substantially

copper and natural impurities, forms a suitable, nonferrous metal for the multi-layer structure of the present device including both cover layers 1 and 11 and the composite fiber material 5, 6, 15, 16.

Fig. 3 shows the cooling pipes or tubes 3 secured to the carrier plate 1, for example, by welding, brazing or soldering the pipe ends 4 in the holes 2, whereby the pipe ends 4 extend substantially at a right angle out of the carrier plate 1. A metal frame 10 is preferably secured to the margin zone 7. The frame 10 is also made of a heat conducting metal such as a copper alloy. The voids between neighboring cooling pipes 3 and the voids between the cooling pipes 3 and the frame 10 are filled with layers of composite fiber material 15, 16 and 17.

Fig. 4 shows the carrier plate 1 and a cover plate 11 prior to their connection to each other. The cover plate 11 is provided at least with one, preferably with several composite fiber layers or plies 12, 13 and 15 which are uninterrupted, except for the margin zone 14 of the cover plate 11. The assembly is performed in an evacuated enclave in a heated condition, whereby the plate 11 is brought down in the direction of the arrow A to be pressed against the frame 10, whereby the plate 11 is tacked to the frame 10. Instead of a separate frame 10, the margins of the cover plate 11 may be angled downwardly and tacked against the margin zone 7 of the

carrier plate 1. The pipe ends 4 are secured in the holes 2 of the carrier plate 1 in a gas-tight manner, for example, by welding, brazing, or soldering as mentioned above.

The tacked components described above are heated in a vacuum, degassed, and then welded together. The resulting structure which is still not compacted is then exposed to a hot isostatic pressing for densification, whereby the fiber coatings of a heat conducting metal are densified to form a matrix metal in the core layer. The result is a compact, densified wall cooling element having a densified core layer. The cooling pipes are open to the pressure during densification and therefore will not be flattened.

Although the invention has been described with reference to specific example embodiments, it will be appreciated that it is intended to cover all modifications and equivalents within the scope of the appended claims.

CLAIMS:

1. A cooling device for cooling a wall comprising a metallic carrier plate, a metallic cover plate, a fiber reinforced composite core structure sandwiched between said carrier plate and said cover plate, cooling ducts in said composite core structure, said composite core structure comprising a heat conducting metal matrix and fibers embedded in said metal matrix, said cooling ducts being embedded in said metal matrix, and inlets and outlets connected through one of said plates to said cooling ducts for passing a coolant through said cooling ducts.

2. The cooling device of claim 1, wherein said fiber reinforced composite core structure comprises a plurality of fiber plies or layers comprising fibers oriented with due regard to tensile stress components effective in the device when the device is in operation.

3. The cooling device of claim 2, wherein said fiber plies comprise at least two outer plies, a first outer ply being positioned next to said carrier plate, a second outer ply being positioned next to said cover plate, said outer fiber plies being uninterrupted by said cooling ducts.

4. The cooling device of any preceding claim, further comprising a metallic frame (10) enclosing said composite fiber core structure on all sides.

5. The cooling device of any preceding claim, wherein said composite fiber core structure comprises fiber cores coated with a metallic coating selected from one of

metals and alloys of which said carrier plate and said cover plate are made.

6. The cooling device of any preceding claim, wherein said heat conducting metal matrix of said composite fiber core construction comprises compacted, heat conducting metal matrix material in which said fibers and said cooling ducts are embedded.

7. The cooling device of any preceding claim, wherein said fibers are made of a fiber core material selected from the group consisting of carbon fibers and silicon carbide fibers.

8. The cooling device of any preceding claim, wherein said carrier plate (1) and said cover plate (11) are made of a material selected from the group consisting of non-ferrous metals, bronze, brass, cooper, aluminum and alloys of non-ferrous metals and copper and aluminum.

9. The cooling device of any preceding claim, wherein at least one of said carrier plate and said cover plate is constructed as a support plate for cooling channels.

10. The cooling device of any preceding claim, wherein said cooling ducts comprise cooling pipes passing through and embedded in said composite fiber core structure.

11. The cooling device of claim 10, wherein said cooling pipes have angled or bent ends extending through holes in one of said plates in a gas-tight manner to form said inlets and outlets.

12. A heat exchanger incorporating a cooling device according to any preceding claim.

13. The cooling device of any of claims 1-11, used as a wall element of a hot gas flow channel, and adapted to pass hydrogen through said cooling ducts.

14. A method for producing a cooling device for cooling a wall comprising a metallic carrier plate, a metallic cover plate, a fiber reinforced composite core structure sandwiched between said carrier plate and said cover plate, cooling ducts in said composite core structure, said composite core structure comprising a heat conducting metal matrix and fibers embedded in said metal matrix, said cooling ducts being embedded in said metal matrix, and inlets and outlets connected through one of said plates to said cooling ducts for passing a coolant through said cooling ducts, the method comprising the following steps:

(a) making holes through a carrier plate made of heat conducting material for insertion of inlet and outlet connectors into said holes,

(b) applying a first fiber composite layer to one surface of said carrier plate without covering said holes and leaving a rim or margin zone of said carrier plate free of said fiber composite layer,

(c) forming cooling ducts with angled ends and inserting said angled ends into said holes, whereby said angled ends form inlet and outlet connectors,

(d) layering further fiber plies onto said cooling ducts for filling voids between neighboring cooling ducts thereby forming said fiber composite core structure, and

(e) enclosing said fiber composite structure between said carrier plate and a cover plate.

15. The method of claim 14, further comprising applying a further composite fiber layer to an inwardly facing surface of said cover plate prior to said enclosing step, without covering a rim or margin zone of said inwardly facing surface of said cover plate.

16. The method of claim 14 or claim 15, further comprising filling voids in said composite fiber structure with matrix metal of the same type as is used for making said carrier plate.

17. The method of claim 16, wherein said filling of voids is performed by any one of floating deposition, infiltration, powder deposition and precipitation of matrix metal.

18. The method of any of claims 14-17, further comprising sealing said angled ends in said holes in a gas-tight manner.

19. The method of any of claims 14-18, further comprising evacuating said composite fiber core structure while performing said enclosing step (e).

20. The method of any of claims 14-19, wherein said enclosing step (e) is performed by any one of welding,

brazing, and soldering.

21. The method of any of claims 14-20, further comprising evacuating said composite fiber core structure following said enclosing step (e), while heating said device to a curing or baking temperature.

22. The method of any of claims 14-21, further comprising evacuating said device following said enclosing step (e) and hot isostatic pressing said core layer without closing said cooling ducts, thereby to fill any other voids in said composite fiber core structure to densify said composite fiber core structure.

Patents Act 1977 **I miner's report to the Comptroller under Section 17** – 26 – **(The Search report)**	Application number GB 9413651.2
Relevant Technical Fields (i) UK Cl (Ed.M) F4S (S7, S41A5, S2M8, S2B12); F1J (JDB, JCA) (ii) Int Cl (Ed.5) F28F (21/00, 21/02, 21/08); F28D (21/00); F02K (1/82, 9/64, 9/97)	Search Examiner T M JAMES Date of completion of Search 5 OCTOBER 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, EDOC	Documents considered relevant following a search in respect of Claims :- 1-22

Categories of documents

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
Y	GB 1456986	(TOKYO PLYWOOD) see Figures 1 and 4 and page 2 lines 46-69	1 at least
Y	GB 1147027	(IIT) see page 2 line 129 - page 3 line 10 and Figures 1 and 4	1 at least
A	EP 0140974	(MITSUBISHI) see page 4 lines 14-26	

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